SPECIAL ISSUE
Original Article

Water: a neglected nutrient in the young child? A South African perspective

Lesley T. Bourne*, Berna Harmse† and Norman Temple‡

Environmental Health Unit, South African Medical Research Council, †Panorama Medical Centre, Panorama, Cape Town, South Africa, and ‡Centre for Science, Athabasca University, Athabasca, Alberta, Canada

Abstract

Water is considered an essential nutrient because the body cannot produce enough water itself, by metabolism of food, to fulfil its need. When the quantity or quality of water is inadequate, health problems result, most notably dehydration and diarrhoea. As a result of contaminated water and poor hygiene, related infections are still a serious problem. Indeed, in the South African setting water availability and sanitation are critical issues because of the prevalence of childhood diarrhoea and also the HIV/AIDS crisis. Though considerable efforts have been made to improve the water and sanitation problems in South Africa – especially with regard to water supply infrastructure – there is still room for much improvement. Water is a healthy alternative to calorie-dense, non-nutritive beverages, such as artificial fruit drinks and soda. The latter should be avoided as they contribute little other than energy and may contribute to overweight and obesity. Also, they displace more nutritious foods from the child's diet. Consumption of fruit juice should also be limited. These issues highlight the need for a specific guideline relating to water intake in the paediatric food-based dietary guidelines.

Keywords: South Africa, water, sanitation, food-based dietary guidelines, paediatrics

This paper has been written to provide evidence in support of the proposed South African paediatric food-based dietary guidelines. The advice for infants aged 6–12 months is: 'Offer your baby of clean, safe water regularly'; for young children >1 year to <7 years, it is: 'Offer children clean, safe water regularly'.

Correspondence: Lesley Bourne, Environment & Health Research Unit, Medical Research Council of South Africa, PO BOX 19070, Tygerberg 7505, Cape Town, South Africa. E-mail: lbourne@mrc.ac.za

Water is considered an essential nutrient because the body cannot produce enough, by metabolism of food, to fulfil its requirement (Kleiner 1999). Indeed, a person's need for water, as such, can be more urgent than that for food. This is something so obvious but taken for granted so regularly that in the 'Manual on the Nutritional Needs of Man' (Lafontaine 1975),

published in 1974, the Food and Agricultural Organization (FAO) and World Health Organization (WHO) omitted the need for water. However, recent literature has paid more attention to the role of water in health (Behrman *et al*. 2004; Ritz & Berrut 2005). The nutrient is essential for metabolism and temperature regulation (Armstrong 2005). Fluid and electrolyte balance plays a pivotal role in maintaining cellular function and acid-base balance. Consuming sufficient water, and the avoidance of dehydration, is therefore vital to good health. This is crucially important in infants and children as they are more susceptible to dehydration than are adults (Kleiner 1999).

Water requirements of infants and children

Per capita, water requirements are up to 1.5 mL $kcal^{-1}$ day^{-1} (Kibel & Wagstaff 1995; Petraccia *et al*. 2006). In the USA, estimations of adequate intakes of water are based on the median total water intake from food consumption surveys: 1.3 L day^{-1} for children aged 1–3 years and 1.7 L day^{-1} for children aged 4–8 years (Kleiner 2004). This includes both liquid water as well as the appreciable amounts supplied with fruit, vegetables and cooked carbohydrate staple foods. The latest South African survey on liquid consumption, focusing specifically on tap water intake, indicates that children have a much lower intake than in the USA. The estimates indicate that children aged 1–4 years consume 380–480 mL day^{-1}, which rises to 500–790 mL day^{-1} in the 5–11 years age group; both estimates vary depending on the population group (Bourne *et al*. 1987). Though underreporting can explain these findings, it may also suggest that South African children are not optimally hydrated.

Babies that are being breastfed on demand are assumed to be well hydrated – a viewpoint supported by the WHO (World Health Organization 2005a). This is because the consistency of breast milk is such that the fore-milk (the watery substance that is expressed initially) quenches thirst while the hind-milk provides essential nutrients. According to the WHO (World Health Organization 2005a), non-breastfed infants need (in addition to the 200–700 mL per day from milk and other foods) at least 400–600 mL per day of extra fluid in a temperate climate and 800–1200 mL per day in a hot climate.

The WHO (World Health Organization 2005a) states that water should be 'offered to infants and children several times a day to ensure that they are satisfied'. A very young child will not necessarily be able to articulate the need for fluids so water should always be easily available. Also, anecdotal evidence suggests that children may think they are hungry when they are actually thirsty.

Dehydration

Several factors place infants and children at a greater risk of dehydration. They have a larger body surface area relative to body weight and a higher body water percentage (Brockenkamp & Vyas 2003). Indeed, 80% of neonatal body weight is comprised of water, with the proportion dropping to between 50% and 60% in adult women and men, respectively (Brockenkamp & Vyas 2003). However, maintaining this balance is more problematic in infants and children, compared with adults, because children's metabolic pathways are immature and they have a decreased capacity to detoxify and excrete hazardous substances. Children's kidneys have a limited capacity for handling the solute load from high-protein intakes required for growth. In infants, decreased concentrating and diluting capacity of the kidneys can lead to abnormal water balance; this may explain the rapidity with which infants dehydrate. The ability to concentrate urine is achieved between 3 and 6 months of age (Brockenkamp & Vyas 2003; Sawka *et al*. 2005). Yet, another factor that makes infants especially susceptible to dehydration is that they are unable to express thirst (Kleiner 1999).

Osmoregulation is almost completely mediated by osmoreceptors in the hypothalamus. Normally, the hypothalamus responds to changes in extracellular tonicity by altering both thirst and secretion of antidiuretic hormone. However, this delicate balance may malfunction in an ill child leading to either fluid retention or excessive fluid loss. Various illnesses can cause disruption in fluid and electrolyte balance, be it acutely or chronically (Popkin *et al*. 2006). This

Table 1. IMCI categories of diarrhoea and associated mortality (WHO 1997).

Type of diarrhoea	% of cases of diarrhoea	% of deaths due to diarrhoea	% of deaths preventable by standard case management
Acute watery	80	50	100
Dysentery	10	15	80
Persistent	10	35	80
Total	100	100	90

IMCI, Integrated Management of Childhood Illness.

Table 2. Water-related diseases: transmission and control*

Transmission route	Diseases	Causes	Control
Water-borne (or washed)	Cholera; typhoid; dysenteries	Drinking faecal material	Improve water quality
Water-washed	Skin and eye infections; louse borne typhus	Lack of water for proper hygiene	Increase water accessibility and reliability; improve hygiene practices
Water-based	Schistomiasis (penetrating skin); guinea worm (ingested)	Pathogen requires aquatic envt for part of life cycle; eating insufficiently cooked aquatic species	Control snail populations; reduce surface water contamination
Water-related insect vector	Sleeping sickness; filiariasis; malaria	Insects that bite or breed near water	Destroy breeding groups; use mosquito netting

*Adapted from Cairncross and Feachem (Cairncross and Feachem 1983).

may produce serious, and sometimes irreversible, neurological consequences because of rapid shifts of water to and from the brain (Brockenkamp & Vyas 2003).

Clinical signs of dehydration occur when there is a significant loss of body water. Early symptoms of dehydration are fatigue, loss of appetite, headache, light-headedness, dry mouth and eyes (Kibel & Wagstaff 1995; World Health Organization 2005a), a burning sensation in the stomach, and dark urine with a strong odour (Kleiner 1999) ['straw-coloured' urine is associated with a state of normal hydration (Popkin *et al*. 2006)]. Signs of advanced dehydration are clumsiness, shrivelled skin, sunken eyes (and fontanelle in children), difficulty in swallowing, dim vision, numb skin, delirium, muscled spasms and painful urination (Kleiner 1999). Dehydration is considered to be severe if the child shows signs of shock or lethargy or loss of consciousness. Thirst is the primary determinant of hydration status, although thirst sets in only after the commencement of dehydration, when total body water loss reaches 1–2% of body mass (Kleiner 1999; Popkin *et al*. 2006). Practical issues concerning the detection of dehydration (Kleiner 1999), such as urine colour, can be taught in communities or industrial settings.

As illustrated in Table 1, diarrhoea is associated with mortality in young children, and Integrated Management of Childhood Illness (IMCI) categorizes the main types of diarrhoea. IMCI emphasizes determining the duration of the diarrhoea, assessing the severity of dehydration and the presence of blood in the stools in order to categorize the type of diarrhoea and propose appropriate treatment (WHO 1997).

Table 2 presents the categories of water-related diseases, their causes and control.

Hygiene and diarrhoeal diseases

All children with acute watery diarrhoea may to some degree be dehydrated (World Health Organization 2005b). Diarrhoea inevitably brings about a state

of electrolyte and fluid imbalance, and a degree of dehydration (Kibel & Wagstaff 1995). Indeed, the majority of diarrhoeal deaths are caused by dehydration.

Diarrhoea has multiple causes and can occur at any age (Kibel & Wagstaff 1995). Its incidence can more often be traced to socio-economic conditions and poverty than to climate and location (Kibel & Wagstaff 1995). Infections, usually with *Escherichia coli* or rotavirus, account for most cases (Thapar & Sanderson 2004). Major causal factors of diarrhoeal disease are transmission by the faecal-oral route (faecal matter being considered one of the most toxic substances on earth) (Kibel & Wagstaff 1995). Stored water is frequently contaminated if hand washing is not practiced (Thapar & Sanderson 2004). Poor domestic hygiene can include animals kept in the proximity of the household. When in the open air, storage containers may provide incubation sites for pathogenic organisms and drinking vessels may be washed in dirty water or contaminated during storage (Joubert *et al*. 2003).

In a systematic review of 17 studies, Curtis and Caincross (Curtis & Cairncross 2004) concluded that hand washing with soap plays an important role in preventing diarrhoeal disease and that hand washing was also correlated with a reduced risk of severe outcome. Unsanitary conditions lead to repeated diarrhoea, worm infestations, skin infections and chronically challenged immune systems, and may also lead to physical and mental stunting (Curtis & Cairncross 2004). Health education is thus needed to promote healthy domestic food practices and communities should be made aware of the importance of hand washing and mechanisms of domestic environmental decontamination (Bartlett 2003).

Children are more susceptible to pathogens than adults as they engage in much exploratory play; they can therefore be exposed to excreta (fingers to faeces to food). Furthermore, their immune systems are not yet fully developed (Curtis & Cairncross 2004). Diseases are more easily transmitted where groups of children are together and where inadequate toilets or hand washing facilities make it easy for transmission from child to child and thence through the community (Bartlett 2003).

Exclusively breastfed children seem to have much less risk from gastro-intestinal infections than those that are bottle-fed or exposed to mixed feeding (Duse *et al*. 2003). One reason for this is that breast milk contains protective antimicrobial factors (Kibel & Wagstaff 1995). Another important explanation is that bottles cannot be sterilized in unsanitary settings. Inadequate storage and preparation of weaning foods all play a part (Feachem *et al*. 1978).

In 1988, a study in Lesotho reported that water source and sanitation were correlated with linear growth in children (Esrey *et al*. 1988). This was again shown in a study by Daniels *et al*. (1991) also in Lesotho. In their case-control study of diarrhoeal morbidity in children under 5 years of age, they showed that latrine ownership was associated with a reduction in the risk of stunting. A more recent 4-year field study of 230 Peruvian children <3 years of age by Checkley *et al*. (2002) showed that improved water supply and sanitation might improve the linear growth of children. Children were included from birth and followed up for the next 35 months. They found that children with the worst circumstances regarding water source, storage and sanitation were 1 cm shorter with 54% more diarrhoeal episodes than those children in optimal conditions. Inadequate water and sanitation were correlated with increased diarrhoeal incidence but were not associated with diarrhoeal duration (Checkley *et al*. 2004).

Treatment of diarrhoea

Acute diarrhoea, usually caused by an infection, lasts for up to 14 days, while persistent diarrhoea is caused secondary to an infection in association with underlying disease, e.g. malnutrition (Bhan *et al*. 2003). Persistent and chronic diarrhoeas often overlap within the individual, but chronic diarrhoeas are usually caused by congenital digestive defects (Bhan *et al*. 2003). Children manifesting severe diarrhoea or vomiting for longer than 24 h should be examined for potential dehydration (Kleiner 1999).

Dehydration is treatable in over 90% of cases by replacing oral fluid loss with oral rehydration solution (ORS) (Fuchs 2001). Although there is proven effi-

cacy for the regular WHO-ORS, recent research has, for example, focused on using a low-sodium solution, called ReSoMaL, in severely malnourished children. It theoretically prevents the development of overhydration, heart failure or both (Alam *et al*. 2004). Alam *et al*. (2004) concluded that ReSoMaL and standard WHO-ORS were similarly efficacious in rehydrating severely malnourished children with diarrhoea and dehydration.

The WHO and the United Nations Children's Emergency Fund (UNICEF) have devised a strategy of IMCI paediatric care in resource-poor settings, and adapted this strategy for management of HIV (World Health Organization 2005b; Qazi *et al*. 2006). According to IMCI recommendations, home preparations are made up of one level teaspoon of salt, eight level teaspoons of sugar and one litre of clear drinking or cooled boiled water. Home preparations are generally used when ORS are not available and diarrhoea or cholera occur, or as an initial line of treatment until ORS become available. Home preparations tend to be less effective because of lack of knowledge on their preparation. The amount of ORS needed is 10–20 mL kg^{-1} body weight per stool passed, given in small dosages. According to the Centers for Disease Control (CDC) (Centers for Disease Control and Prevention 2003) and the IMCI recommendations, breastfeeding should continue when a child is suffering from diarrhoea. The CDC warns that problems arise when children are administered adult treatments for diarrhoea – emphasizing the well-known fact that children are not small adults. Signs of overhydration include oedema of the eyelids and extremities (Centers for Disease Control and Prevention 2003).

Water supplies and the challenges of hygiene

Water insufficiency and sanitation is a crisis, especially in much of Asia and Africa (Bartram *et al*. 2005), and is thwarting progress towards the Millennium Development Goals (World Health Organization 2004) in many countries.

One of the great challenges of sustainable development is the need for and adequate water supply to rural communities (Momba *et al*. 2004; World Health Organization 2004). Inadequate water and sanitation have a negative impact on children's health in developing countries (Bartram *et al*. 2005). In South Africa, water supplies are insufficient, although much has been performed to improve the situation in the last decade (Bartlett 2003).

Regarding sanitation, according to data from the 2001 South African census, only one in seven houses have access to toilet facilities (Statistics South Africa 2001). Comparing census data from 2001 with a South African National Burden of Disease Study in 2000 shows that the Limpopo Province and the Eastern Cape have the highest and second highest mortality, respectively, from diarrhoeal disease, and these are also the two provinces with the highest percentage of people with no toilet facility (Statistics South Africa 2001; Bradshaw *et al*. 2006). As a result of contaminated water and poor hygiene, related infections are still a serious problem. In particular, in 2000 diarrhoeal disease caused 10% of child deaths in South Africa, a proportion exceeded only by HIV/AIDS and low birthweight (Bradshaw *et al*. 2006). Cholera (*Virbrio cholerae*) is another serious problem. It is a highly infectious disease and the transmission to humans is mainly through contaminated water (World Health Organization 2005a). It frequently occurs in South Africa, with outbreaks in 1980–1984 and from 2000 to 2002, especially along the eastern seaboard (World Health Organization 2005a).

In low-income areas, space constraints necessitate that water storage is mostly performed in small containers. These are often kept open inside a dwelling and are thus susceptible to faecal and other contamination (Joubert *et al*. 2003). By contrast, large containers are generally kept closed and outside, which is far safer. In order to counter the risk of microbial contamination, health professionals frequently advise sick individuals to boil water. However, various barriers may hinder this from being performed, including local beliefs and customs, lack of social support, expenses involved and maternal depression (McLennan 2000). One particular challenge concerns HIV-positive mothers (Doherty *et al*. 2006). Despite the risk of infecting the infant with HIV, breastfeeding may still be advisable in households where

hygiene is lacking and where contaminated bottles and formula milk pose a risk of disease (Coutsadis *et al*. 1999; Dorosko & Rollins 2003). South African water policies have adopted a value of 25 L of water per person per day to be adequate for ingestion, personal hygiene and sanitation (Department of Water Affairs and Forestry, Department of Health, Water Research Commission 1998). However, with the crisis of HIV/AIDS, it is unclear how much more water per person is needed to uphold standards of sanitation, especially in affected households in which home-based care becomes necessary.

Water quality

The term potable is only used where, among other characteristics, water adheres to standards for smell, taste and colour. The testing of drinking water includes physico-chemical, biological and organic aspects (Petraccia *et al*. 2006). Drinking water should be examined for indicators of pollution to ensure that it is safe and free of pathogens. Indicator systems that are able to reveal the presence of pathogens and related health risks are generally used (Berg & Berg 1978). However, some indicators specifically address treatment efficacy with very little emphasis on human health. The coliform group of bacteria has been used much more than any other indicator group for monitoring drinking water because it addresses both health and treatment efficacy objectives (Genthe & Seager 1996). The basis of a joint venture between the South African Department of Water Affairs and Forestry and the Department of Health (Department of Water Affairs and Forestry, Department of Health, Water Research Commission 1998) was the definition of five classes of water quality in terms of suitability of the water for drinking, ranging from Class 0 (ideal) to Class 4 (unacceptable) (Table 3).

High concentrations of people and their wastes in urban areas increase the risk of infection with pathogens, leading to a greater need for adequate water and sanitation (Curtis & Cairncross 2004). Flies carry diseases, and are particularly attracted by pit latrine or bucket system toilets. Facilities should be fly proof and should be properly maintained (Thapar & Sanderson 2004). As stressed earlier, public awareness should be raised on health and sanitation.

Beverages and non-infectious diseases

The relationship between beverages and health extends far beyond issues of hygiene. Beverages can have an impact on the risk of various non-infectious diseases related to lifestyle. In particular, high intakes of energy-dense beverages may contribute to overweight (Kleiner 1999; Newby *et al*. 2004). However, there is still controversy around soft drinks and fruit juices and their relationship with overweight, with some studies showing no correlation (Marshall *et al*. 2003). Quite apart from the possible role of these beverages in excess weight gain, there are several other reasons why their consumption should be limited. First, sugary drinks may adversely affect teeth. Consumption of sugar-rich beverages or fruit juice is likely to displace formula or milk from the diet and thereby reduce intake of nutrients critical for growth and development (Kleiner 1999). Clearly, we

Table 3. Classes of water quality*

Class	Characterisation	Suitability for drinking
Class 0	'Ideal'	Safe for lifetime use
Class 1	'Good'	Safe for lifetime use
Class 2	'Marginal'	Safe for use under certain conditions but should be regarded with caution
Class 3	'Poor'	Considered unsafe for use and should be treated. The water may be used for short-term emergency supply but only where no alternative supplies are available
Class 4	'Unacceptable'	Considered unsafe for use and should be treated. Water in this class is unsafe even for short-term emergency use

*Department of Water Affairs and Forestry, Department of Health, Water Research Commission (1998).

must differentiate between beverages where the main ingredient is sucrose (or fructose) and fruit juice. The WHO (World Health Organization 2005a) states that sugary drinks should be avoided because they contribute little other than energy (i.e. they are 'empty calories') and suppress the child's appetite for more nutritious foods. Consumption of fruit juice is obviously far preferable because of its content of micronutrients and phytochemicals.

In the light of the current world problem of obesity, water offers a healthy alternative to calorie-dense, non-nutritive beverages, such as artificial fruit drinks and soda (Kleiner 2004). Popkin *et al*. (2006) recently stated that calorie-free beverages, preferably water, should meet most, if not all, human fluid needs. In addition, water is free of possibly unhealthy additives found in commercially available drinks.

Fluoride

The USA, Australia, New Zealand, Canada and Ireland have fluoridated water, but many other countries have also yet to set fluoridation in motion (Kauffman 2005; World Health Organization 2005c). South Africa is one such country: despite many efforts to fluoridate water, primarily to prevent dental caries, this has not been introduced.

According to Kauffman (Kauffman 2005), recent research has shown only slight improvements from water fluoridation in 5-year-old children, although topical treatments may be effective. However, the WHO (World Health Organization 2005c) actively advocates fluoridation of milk and toothpaste. Pehrsson *et al*. (2006) state that although the role of fluoride in the reduction of dental caries is well described, especially in children, assessment of fluoride intakes from fortified sources should be carried out to develop further knowledge on fluorosis.

Conclusion

Though considerable efforts have been made to improve the water and sanitation problems in South Africa – especially with regard to the rate of delivery on water supply infrastructure (Statistics South Africa 2001) – there is still room for a great deal of improvement and many groups are in need of intervention, particularly with scientifically evaluated health promotion initiatives.

The South African paediatric food-based dietary guidelines (PFBDGs) could play an important role in this respect by encouraging young children to 'drink plenty of safe, clean water'. This is an enormous challenge in many contexts as water is anecdotally perceived to be 'tasteless' and 'boring', particularly among those children exposed to the aggressive marketing strategies of beverage companies.

References

Alam N.H., Hamadani J.D., Dewan N. & Fuchs G.J. (2004) Efficacy and safety of a modified oral rehydration solution (ReSoMaL) in the treatment of severely malnourished children with watery diarrhoea. *Journal of Pediatrics* **143**, 614–619.

Armstrong L.E. (2005) Hydration assessment techniques. *Nutrition Reviews* **63**, S40–S54.

Bartlett S. (2003) Water, sanitation and urban children: the need to go beyond 'improved' provision. *Environment and Urbanization* **15**, 57–70.

Bartram J., Lewis K., Lenton R. & Wright A. (2005) Focusing on improved water and sanitation for health. *Lancet* **365**, 9461.

Behrman R.E., Kliegman R.M. & Jenson H.B., eds. (2004) *Nelson Textbook of Pediatrics*, 17th edn. W B Saunders: Philadelphia, PA.

Berg G. (1978) The indicator system. In: *Indicators of Viruses in Water and Food* (ed. Berg G.), pp 1–13. Ann Arbour Sci: Ann Arbor, MI.

Bhan M.K., Bhandari N. & Bahl R. (2003) Management of the severely malnourished child: perspective from developing countries. *British Medical Journal* **326**, 146–151.

Bourne L.T., Bourne D.E., Watermeyer G.S. & Klopper J.M.L. (1987) A liquid consumption survey of individuals in greater Cape Town. Report to the Water Research Commission by the Department of Community Health, University of Cape Town. WRC-report 74/2/87.

Bradshaw D., Nannan N., Laubscher R., Groenewald P., Joubert J., Nojilana B., *et al.* (2006) South African National Burden of disease study 2000: Estimates of provincial mortality: Summary report, 13p.

Brockenkamp B. & Vyas H. (2003) Understanding and managing acute fluid and electrolyte disturbances. *Current Paediatrics* **3**, 520–528.

Cairncross S, Feachem RG. (1983) *Environmental Health Engineering*, 2nd edn. John Wiley: Chichester. Checklist of water-related diseases, 285–290.

Centers for Disease Control and Prevention. (2003) Managing acute gastroenteritis among children. oral rehydration, maintenance and nutritional therapy. *MMWR* **52** (No RR-16), 1–20.

Checkley W., Gilman R.H., Black R.E., Lescano A.G., Cabrera L., Taylor D.N., *et al.* (2002) Effects of nutritional status on diarrhoea in Peruvian children. *Journal of Pediatrics* **140**, 210–218.

Checkley W., Gilman R.H., Black R.E., Epstein L.P., Cabrera L., Sterling C.R., *et al.* (2004) Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. *Lancet* **363**, 112–118.

Coutsadis A., Pillay K., Spooner E., Kuhn L. & Coovadi H. (1999) influence of infant – feeding patterns on early mother-to-child transmission of HIV-1 in Durban, South Africa: a prospective cohort study. *Lancet* **354**, 471–476.

Curtis V. & Cairncross S. (2004) Effect of washing hands with soap on diarrhoeal risk in the community: a systematic review. *Lancet* **3**, 275–281.

Daniels D.L., Cousens S.N., Makoae L.N. & Feachem R.G. (1991) A study of the association between improved sanitation facilities and children's height in Lesotho. *European Journal of Clinical Nutrition* **45**, 23–32.

Department of Water Affairs and Forestry, Department of Health, Water Research Commission. (1998) *Quality of Domestic Water Supplies*. **Vol. 1**. Assessment Guide, 2nd edn. Water Research Commission: Pretoria.

Doherty T., Chopra M., Nkonki L., Jackson D. & Greiner T. (2006) Effect of the HIV epidemic on infant feeding in South Africa: 'When they see me coming with the tins they laugh at me'. *Bulletin of the World Health Organization* **84**, 90–96.

Dorosko S. & Rollins N. (2003) Infant formula preparation by rural and semi-rural women in South Africa. *Food Policy* **28**, 117–130.

Duse A.G., Da Silva M.P. & Zietsman I. (2003) Coping with hygiene in South Africa, a water scarce country. *International Journal of Environmental Health Research* **13**, S95–S105.

Esrey S.A., Habicht J.-P., Latham M.C., Sisler D.G. & Casella G. (1988) Drinking water source, diarrhoeal morbidity, and child growth in villages with both traditional and improved water supplies in rural Lesotho, South Africa. *American Journal of Public Health* **78**, 1451–1455.

Feachem R., Burns E. & Cairncross S. (1978) *Water, Health and Development*. TRI-MED Books Ltd: London.

Fuchs G.J. (2001) A better oral rehydration solution? *British Medical Journal* **232**, 59–60.

Genthe B. & Seager J. (1996) *The Effect of Water Supply, Handling and Usage on Water Quality in Relation to Health Indices in Developing Communities*. WRC Report Number: 562/1/96.

Joubert G., Jagals P. & Theron L. (2003) Water-related household practices in section K, Botshabelo, and associations with diarrhoea. *Southern African Journal of Epidemiology and Infection* **19**, 13–19.

Kauffman J.M. (2005) Water fluoridation: a review of recent research and actions. *Journal of American Physicians and Surgeons* **10**, 38–44.

Kibel M.A. & Wagstaff L.A. (1995) *Child Health for All: A Manual for Southern Africa*, 2nd edn. Oxford University Press: Cape Town.

Kleiner S.M. (1999) Water: an essential but overlooked nutrient. *Journal of the American Dietetic Association* **99**, 200–206.

Kleiner S.M. (2004) The art and science of hydration. *Acta Pædiatrica* **93**, 1557–1558.

Lafontaine A. (1975) Introductory report. In: *Commission of the European Communities, Hardness of Drinking Water and Public Health*. Pergamon Press: Oxford.

McLennan J.D. (2000) To boil or not: drinking water in a peri-urban barrio. *Social Science and Medicine* **51**, 1211–1220.

Marshall T.A., Levy S.M., Broffitt B., Eichenberger-Gilmore J.M. & Stumpf P.J. (2003) Patterns of beverage consumption during the transition stage of infant nutrition. *Journal of the American Dietetic Association* **103**, 1350–1353.

Momba M.N.B., Tyafa Z. & Makala N. (2004) Rural water treatment plants fail to provide potable water to their consumers: the Alice water treatment plant in the Eastern Cape province of South Africa. *South African Journal of Science* **100**, 307–310.

Newby P.K., Peterson K.E., Berkey C.S., Leppert J., Willett W.C. & Colditz G.A. (2004) Beverage consumption is not associated with changes in weight and body mass index among low-income preschool children in North Dakota. *Journal of the American Dietetic Association* **104**, 1086–1094.

Pehrsson P.R., Perry C.R., Cutrufelli R.C., Patterson K.Y., Wilger J., Haytowitz D.B., *et al.* (2006) Sampling and initial findings for a study of fluoride in drinking water in the United States. *Journal of Food Composition and Analysis* **19**, S45–S52.

Petraccia L., Liberati G., Masciullo S.G., Grassi M. & Fraioli A. (2006) Water, mineral waters and health. *Journal of Clinical Nutrition* **25**, 377–385.

Popkin B.M., Armstrong L.E., Bray G.M., Caballero B., Frei B. & Willett W.W. (2006) A new proposed guidance system for beverage consumption in the United States. *American Journal of Clinical Nutrition* **83**, 529–542.

Qazi S.A. & Muhe L.A. (2006) Integrating HIV management for children into the integrated management of childhood illness guidelines. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **100**, 10–13.

Ritz P. & Berrut G. (2005) The importance of good hydration for day-to-day health. *Nutrition Reviews* **63**, S6–S31.

Sawka M.N., Cheuvtony S.N. & Carter R. (2005) III. Human water needs. *Nutrition Reviews* **63**, S30–S39.

Statistics South Africa. (2003) *Census 2001: Census in Brief*. Statistics South Africa: Pretoria. Available at: http://www.statssa.gov.za

Thapar N. & Sanderson I.R. (2004) Diarrhoea in children: an interface between developing and developed countries. *Lancet* **363**, 641–653.

World Health Organization. (1997) Reducing childhood mortality from major childhood diseases. Fact Sheet 180. Available at: http://www.who.int/child-adolescent-health/New_publications/IMCI/fs_180.htm

World Health Organization. (2004) Flagging global sanitation target threatens other Millennium Development Goals. *Bulletin of the World Health Organization* **82**, 234–235.

World Health Organization. (2005a) *Guiding Principles for Feeding Non-Breastfed Children 6–24 Months of Age*. World Health Organization: Geneva. Available at: http://www.who.int

World Health Organization (WHO). (2005b) *Pocket Book of Hospital Care for Children: Guidelines for the Management of Common Illnesses with Limited Resources.* World Health Organization: Geneva.

World Health Organization. (2005c) The effective use of fluorides in public health. *Bulletin of the World Health Organization* **83**, 670–676.